

TRANSITION PATHS TO NEXT-GENERATION WIRELESS SERVICES

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1. Introduction

Although communications policy has important repercussions, its direct and indirect effects are rarely considered when crucial decisions are made. In part, this is due to the increasingly diverse environment of the information and communication industries. It is also partly due to the limitations of the traditional static framework for policy analysis in examining the dynamic effects of policy. Moreover, given the prevailing trust in “unregulated” market forces, it is often overlooked that markets need an appropriate legal and regulatory framework to unfold, even if detailed interventions are kept at minimum. Although the options for designing this framework of mobile markets are constrained by the institutional endowment of a country or a region, important aspects of it can be designed by policy-makers. Despite the importance of this overall framework, regulatory theory and practice has paid relatively little attention to it.

This paper is a first step toward closing this gap. We approach our theme both theoretically and empirically using the example of wireless communications in the European Union and in the United States. Using a neo-institutional economic approach, we first develop a framework that allows exploring the dynamic interactions of technology, policy, and business strategy under conditions of uncertainty. We then examine how policy choices affect the overall evolution of the wireless industry. Multiple technology platforms for the configuration of next-generation wireless services are available, including 2.5G, 3G, licensed 4G and unlicensed applications, such as WLANs. These platforms differ in important technical and economic characteristics. The mix of technology will be influenced by the legal and regulatory framework of the industry. The most important aspect of public policies towards wireless include: (1) spectrum management (e.g., initial assignment via auction or beauty contest, existence of secondary markets); (2) the specific market design (e.g., permission of network sharing, obligation to provide open access to mobile virtual network operators, ability to use 2G spectrum for 3G services); and (3) the standardization regime (e.g., mandatory or industry-driven).

Using this framework, we study the interaction of technology, policy, and business decisions in the 3G and WLAN markets in the European Union and in the United States. The paper contributes to the theoretical and applied policy-research in four areas. First, it develops a dynamic framework for the study of next-generation wireless services. Second, it provides detailed empirical data on the market development strategies in 3G and WLANs in the European Union and the United States to advanced wireless. Third, it enhances our understanding of the

direct and indirect effects of policy decisions on the transition paths to advanced wireless. Lastly, it provides a framework to develop recommendations for designing a framework for the transition to 4G wireless services.

2. Conceptual framework

The dynamic interaction of technology, public policy, supplier strategies, and consumer behavior shape the overall evolution of the wireless industry. These areas co-evolve with each other, that is, they influence each other but do not fully determine the other area. Overall sector performance is an emergent property from this interaction. Of particular interest is how these factors influence the rate and level of diffusion of services, the mix of wireless technologies and services available, the speed of innovation in wireless services including the transition to new generations of wireless services, and the prices charged for services. Under conditions of imperfect information and uncertainty, agents such as network operators, equipment manufacturers, content providers and buyers act based upon their perception of the environment and expectations as to future developments. The legal and regulatory rules governing the provision of wireless services, including the spectrum management regime, provisions regarding network sharing or third party open access, are an important part of this environment (and may themselves be the target of business strategies). Whether a chosen course of action was a good choice will only be revealed after the fact. Although in practice these factors are linked by many feedbacks, for the purposes of this section we will first explore them one at a time, assuming that other things remain equal. Subsequently, their interaction will be discussed and compatible and incompatible constellations distinguished.

2.1 Technology

Wireless technology has important attributes that constrain and affect business decisions. Its capabilities obviously constrain the type of services that can be offered. For example, the bandwidth available in different wireless platforms or the reach and coverage of the signal limit the range of possible applications. Thus UMTS is better suited to data communications applications that require good coverage of larger areas whereas WiFi may be better suited to provide high data rates over short distances. However, technology is changing fast and new solutions may alter the range of applications that can be configured on any platform. The technology platform also affects the coordination requirements and processes between the

participants in the mobile value chain. Compared to 2G wireless services, 3G has a more complex value chain that may cause significant transaction costs between firms unless new arrangements are found to keep them at bay. From an economic perspective, each platform can be characterized by a unique cost function. Of particular importance for investment into new applications are the level of sunk costs and the expected returns, as they jointly determine its risk. 3G networks are less scalable than networks of WiFi access points. Hence, other things equal, the minimal initial fixed cost of a 3G network is significantly higher than that of a WiFi network. On the other hand, due to the present short reach of WiFi, it is cheaper to cover larger areas using 3G technology. Thus, apart from differing functionality, at current costs, 3G networks seem to be a superior technology for certain applications if wide coverage is desired whereas WiFi networks perform better if the coverage area is small. This may change if WiMAX technology succeeds, which would allow expanding the reach of WiFi by several orders of magnitude to >50km. Moreover, one needs to bear in mind that the different platforms do not provide the same functionality and thus are only partial substitutes. Nevertheless, as the capabilities of one affect the market conditions of the other, they need to be seen as co-evolving.

2.2 Policy

Wireless policy interacts with these technological conditions. It can reinforce or mitigate the economic features inherent in the technology platforms¹. Of utmost importance for the evolution of wireless services is the spectrum management regime, policies governing the relations between network service providers and other players, as well as other obligations imposed on service providers. During the past decade, spectrum auctions have emerged as the preferred assignment mechanism in many countries. Researchers are divided between those who principally think that they are superior mechanisms for the assignment of spectrum rights and those who hold more skeptical views. Although auction design is well understood in theory, the practice is often dominated by greed or poor judgment (Melody 2001; Klemperer 2004). Several authors have pointed to a more fundamental flaw in the arguments advocated by proponents of auctions: that the market conditions required for auctions to be efficient are often not met in practice. For example, in the highly dynamic wireless markets, firms typically do not have a good understanding of the demand for their services; as firms do face long-term financial

¹ While policy can shape the fundamental aspects of the technology in that technologies are often designed to work within a given policy framework, here we consider the influence of policy on the *deployment* of the technology.

constraints, money spent for licenses may reduce the resources available to invest into network infrastructure; and in markets with high sunk costs the market structure may be endogenous to the entry conditions (Noam 1998; Gruber 2001). This does not necessarily disqualify auctions as an assignment mechanism but it requires an assessment of the advantages and disadvantages of auctions and specific auction designs as opposed to other forms of spectrum access (Bauer 2003). Among these effects are the implications for the investment behavior in the service, for corporate strategy and its effects on market structure, the innovation pattern in wireless technologies, and the performance of the sector from a consumer perspective.

The past few years have also seen a broad challenge to the notion that the establishment of exclusive rights in spectrum use, as was the dominant practice since the early days of wireless, is the most efficient approach. One set of authors proposes to replace the present regime of exclusive usage rights with comprehensive private property rights (Spiller and Cardilli 1999; Hazlett 2001; Kwerel and Williams 2002). Against spectrum privatization and for the establishment of a comprehensive open access regime argue Benkler (2003), Werbach (2004) and Reed (2002), among others. Faulhaber and Farber (2003) and Bauer (2004) hold intermediate positions, arguing that both regimes have unique advantages and disadvantages, which would suggest establishing these regimes in parallel. For example, as it facilitates the appropriation of a risk premium, a property regime may be more conducive to services that require high upfront investment. On the other hand, a commons regime may be an efficient way to organize wireless services that are predominantly local in scope or do not require high sunk costs. Whereas this debate has not been settled, policy makers in the EU and in the U.S. have created open access bands in addition to the traditional licensed regimes.

In addition, to the market access framework, other dimensions of wireless policy affect the economics of the industry. Among these rules are roll-out requirements attached to licenses, provisions governing access by third parties to the network platform, and other obligations that may be imposed on carriers. The design of this legal and regulatory framework can mitigate or aggravate the overall business risk in the sector although little attention seems to be paid to them. Roll-out requirements attached to licenses typically add to the sunk costs and thus sector risk. Likewise, limitations on the flexibility of spectrum use may increase risk. For example, at least initially, in most European nations 3G spectrum was to be used exclusively for the provision of 3G services (2G spectrum could not be used to provide 3G services). Mandatory third party

open access provisions, as were, for example, adopted in Sweden, may have positive or negative effects on the service provider. Lastly, the ability to share network facilities with other service providers has the potential to reduce sunk costs and thus the risk of entering the 3G market. In an ideal auction the effects of these provisions would be reflected in the price paid for a license. However, under imperfect conditions this is not necessarily the case and the specific sector setup therefore will have repercussions for the evolution of the industry.

2.3 Business strategy

Technology and policy are important factors shaping and constraining business strategy in the wireless industry. Although the intensity of competition is generally higher than in wireline service, wireless service providers typically operate in an imperfectly competitive or even oligopolistic environment. Widespread strategies to reduce competitive pressure, such as the introduction of switching costs (e.g., multi-year contracts with penalties for early termination) include price discrimination (e.g., two and multi-part pricing schemes), and abuses of monopolistic market segments (e.g., high mobile termination charges). As a result, service providers have some discretion over prices and will attempt to differentiate their services from other suppliers. We will not discuss in detail the demand for wireless services although we will tacitly assume that it is normally behaved. That is, the quantity demanded will increase inversely with the price of service, lower service quality will have a negative effect on demand, and income a positive. We will further assume that service providers have only incomplete information as to the market level of demand for services and as to their specific demand. Our goal is to understand how the technological and policy aspects discussed above affect the choice of business strategy within a specific service and with regard to the mix of services available in the market. Business strategy is also dependent on management's attitude towards risk, the resource base of a firm, and other factors, such as the general culture of operating a business, that we will not investigate in detail. Other things equal, it is probable that an increase in sunk cost will increase the risk of an investment project. Under conditions of uncertainty with regard to demand and competitor strategy, firms will adjust their strategy to manage risk. One common approach is to time investment projects to wait until more information about the market conditions is revealed (Dixit and Pindyck 1994). In markets with network effects, the advantages of waiting will have to be weighed against any existing first mover advantages (Shapiro and Varian 1999).

2.4 Standardization

Technology, policy and business strategy are strongly interrelated with standardization issues. Standardization is an important coordination issue that can affect business processes and shapes the future structure of a market. In many markets, a single or a small number of technologies emerge as a standard due to the pressure of compatibility for manufacturers, distributors, and the end consumer experience. Once a standard is established, the related forms of market uncertainty are reduced (Funk and Methe 2001). With these advantages standards have become core to firm strategizing. Firms that are able to standardize their product or process industry-wide may be able to reap first mover advantages and those who invest in the winning standard can create economies of scale and benefit from less uncertainty in consumer demand.

Two different standardization approaches are often distinguished: (1) market-based and (2) committee-based standardization (Farrell and Saloner 1988). In market-based standardization, competing technologies/standards are introduced into the market that then selects a de-facto standard once the markets have stabilized. This process of standard selection is also often called “ex-post standardization”. In contrast in committee-based standardization, first a standard is selected ex-ante in a committee (that is outside of the market) and then the agreed upon standard is introduced into the market. Committee-based standardization often relies on standard setting bodies or relates to formal institutions such as ETSI, IEEE etc. A related question is whether a standard, once developed, should be mandatory for market participants (as was the case in AMPS in the United States and GSM in Europe), recommended (as is the case in UMTS) or voluntary (as was the case in digital wireless in the U.S. and presently in the 802.11 family of protocols).

Criticisms of the pure market and the pure committee based models of standardization have recently become abundant (Keil 2002). To a large extent, literature on the economics of standards and compatibility assumes that standardization has benefits that make it a socially desirable outcome (Gandal, Salant et al. 2003). The key arguments in favor of the centralized committee-based approach to standardization are that it aims for larger social good, larger economies of scale, avoidance of future anti-trust litigations to control the market and provides affordable prices to the consumers. On the other hand the proponents of the ‘decentralized’ market-based standardization approach point to the basic drawbacks of the centralized approach, which include stifling innovation in an immature market, static inflexible outlook toward a

dynamic market, a time consuming approach, and the possibility of mandating an inferior standard/technology (Lee, O Neal et al. 1995). In a study of digital wireless rollout it was found that the centralized approach taken in Europe foregoes the benefits of competition in research and development. This can be contrasted with the US approach, which was to encourage competition for a period of time before deciding on a standard. It is generally agreed that the US market-based approach led to a better outcome for the US in terms of CDMA, albeit at the cost of initially slower diffusion of digital wireless, as four competing networks were rolled out (Gandal and Waverman, 2003).

To balance the pros and cons of the market and standardizing bodies, there have been increasing instances of a hybrid model for standardization that combines elements of market and committee based processes. In this model a limited number of standard candidates are created by semi-open groups of firms. These candidates are then introduced into the market that decides about their adoption thus leading to a de-facto standard. Examples of such standardization initiatives include Symbian, SyncML, or Mobey (Keil 2002). Another hybrid model known as Public Available Specifications (PAS) is also a type of mixed market-committee based standardization. In this model a standard is made publicly available for anyone to use, which in turn uses market forces to lead to a de-facto standard.

3. “Next generation” wireless technology and standards

The widespread convention of referring to wireless technology platforms as “generations” is somewhat misleading, as it seems to suggest a linear progression from one generation to the next. Whereas this may have been accurate for the evolution of 1G through 2.5G services, 3G and 4G platforms are currently developed and introduced to the market in parallel. These include solutions with relatively short range (802.11a, 802.11b (WiFi), 802.11g, HiperLAN, RadioLAN, HomeRF, or Bluetooth) and platforms with extended range, such as 802.16 (WiMAX), HiperMAN, or 802.20. Depending on their eventual technical capabilities, these platforms may serve as complements or (partial) substitutes to 3G. Apart from technical features there are also significant economic differences. As these platforms are configured in unlicensed spectrum bands, entry costs associated with 3G do not exist; on the other hand, service providers do not enjoy the protection against new market entrants resulting from the exclusive assignment of spectrum in 3G bands. This juxtaposition of economically very different regimes creates an interesting mix of incentives and may influence the overall organization of the industry. In this

section we will briefly review key technical and policy characteristics. Emerging business strategies will be the topic of section 5.

Next generation wireless technologies evolve in different environments. 3G platforms were conceptualized against the background of network-centric 2G services. Industry, leery of having to support multiple interfaces and technology in various national markets, and policy-makers saw benefits from a global standardization of the service. This led to the development of the IMT-2000 (International Mobile Telecommunications-2000) concept, which was first discussed by the International Telecommunication Union (ITU) in the mid-1980s. Initially, there was hope that one single global standard might emerge. However, competition between several consortia and conflicts of interest prevented this outcome. In 1999, the ITU adopted five families of standards for IMT-2000: CDMA2000, WCDMA, TD-SCDMA, UWC-136 and DECT+. Among them, CDMA2000 and WCDMA play the dominant roles in the current mobile data markets. All of the commercial mobile data services that have been launched are based on either the CDMA2000 or the WCDMA standard. Their potential competitor is TD-SCDMA (Time Division-Synchronous Code Division Multiple Access). It was co-developed by CATT (China Academy of Telecommunication Technology) and Siemens and may be applied in the world's largest mobile communication market, China.

The principal criterion the ITU uses for defining a 3G service is transmission speed. A 3G service must fulfill the following requirements.

- 2Mbps or higher for stationary users and indoor environments
- 384kbps for pedestrians
- 144 kbps for high-speed moving vehicles

W-CDMA and CDMA2000 1XEV are the two most widely deployed technologies that reach these required transmission rates, although these rates are currently not achieved in environments with large numbers of users.

The ITU's standardization efforts occurred in a context in which Europe was keen to maximize its investment in GSM. Thus, in their eyes, any 3G standard should provide an easy transition from GSM and GPRS. This has been realized in UMTS (Universal Mobile Telecommunication System), which is synonymous with W-CDMA. The U.S. has taken a market-based approach to 3G. As with 2G, firms are choosing their network technology standard individually and this is continuing the fragmentation that occurred in 2G. Some firms

are now adopting GSM technology to be able to follow the evolution to UMTS. However, others have opted for CDMA2000 1X EV, which includes CDMA2000 1XEV-DO (Evolution-Data Optimized) and CDMA2000 1X EV-DV (Evolution- Data and Voice). CDMA2000 1X EV-DO is an upgrade of CDMA2000 1XRTT. Its transmission rate can be up to 2.4Mbps. As for EV-DV, it is a higher upgrade whose transmission rate can be up to 5.2Mbps. Still, no commercial services based on EV-DV have been launched.

Emerging advanced wireless platforms were developed for different communications purposes and in a more diverse, fragmented approach. For example, Bluetooth was developed by a consortium of firms (Ericsson, IBM, Intel, Nokia, and Toshiba) to allow short-range communication between mobile devices (phones, PDAs), computers, and other peripherals. A working group of the Institute for Electrical and Electronics Engineers (IEEE) developed the 802.11 family of standards, which is widely used for wireless local area networking (WLANs). 802.11 is promoted on a global scale by the WiFi Alliance, a non-profit industry group of more than 200 firms, for short-range data communications. 802.16 and ETSI HiperMAN are promoted by the WiMAX Forum, a non-profit consortium of more than 120 firms, for medium and long-range wireless broadband networking. As these platforms were developed in license-free spectrum space in the 2.4 and 5GHz bands, they follow a very different technical-economic logic. Originally designed to offer complementary features to 3G, the development of multi-protocol devices enables them to offer substitute services, at least in certain areas. This alters the economic position of players in the 3G market and will likely have repercussions for the evolution of the industry overall, as will be discussed in more detail below.

There are also initiatives to define a 4G successor standard to 3G although at this point in time it is uncertain whether these attempts will prevail. With the increasing sophistication of digital wireless technology and the availability of cost-effective converters between standards and protocols, the rationale for a common standard may become less convincing. As a concept 4G is yet to be fully explored, let alone standardized, by any international organization. For some 4G is defined as a cellular telecommunication technology that is compatible and integrated with other wireless technologies like WLAN, Bluetooth, IPv6, etc. For others, 4G is a cellular telecommunication system with bandwidths greater than 2Mbps. Given this initial split there are several established and newly formed consortia working to define 4G and their efforts shall be briefly described.

There are many standardizing and industry/academic research organizations at a global system level, which are involved in outlining the vision and requirements for the fourth generation of mobile systems. A few examples include the International Telecommunication Union – Radio-communication sector (ITU-R), the Wireless World Research Forum (WWRF), and the Fourth Generation Mobile Forum (4GMF). ITU-R after putting forth the 3G IMT2000 vision is currently in the process of envisioning 4G. ITU-R is probably the most well established and trusted organization at the global level for 4G visions. According to the ITU-R, 4G is expected to be standardized from 2007 and will be deployed from about 2010 on. The ITU-R is still not clear on the direction of envisioning 4G and is divided into two major groups. One group is looking toward 4G in terms of high data rates (up to 100 Mb/s) to differentiate it from the 3G telecommunication systems and the other is expecting an Open Wireless Architecture (OWA), which provides room for inter-technology integration between most if not all radio communication systems like WLAN, Bluetooth, Cellular, Satellite communications etc.

Since 4G on its introduction will find many predecessor systems operational, inter-working between 4G and other radio access systems in terms of horizontal and vertical handover and seamless services with service negotiation, including mobility, security, and Quality of Service (QoS), will be of high importance. Further ITU-R envisions a steady and continuous evolution of existing radio access networks for the B3G (Beyond 3G) systems into enhanced and newly developed elements of cellular systems and nomadic wireless access systems. Therefore, a push toward an Open Wireless Architecture, based on the converged broadband wireless platform, seems like an important aspect of what the next generation of mobile telecommunication systems might look like.

Several industrial/academic bodies were formed to explore the future of mobile telecommunication systems beyond third generation. These organizations have an important role to play in shaping the future of 4G. In 2000, there were only 8 organizations involved in 4G research and development. By 2002, there were over 200 companies and research institutions on various 4G projects. In 2003, the 4G community expanded to over 2500 bodies worldwide². Among the various existing, established and upcoming industry/research organizations are the Wireless World Research Forum (WWRF) and 4th Generation Mobile Forum (4GMF). The objective of the WWRF, which was officially created on December 2000 with over 150 members

² <http://www.4gmf.org/>

from industry and academia, is to formulate visions on strategic future research directions in the wireless field. It is intended to constructively contribute to the work done within the ITU and other industrial consortiums and standardizing bodies. On the other hand, 4th Generation Mobile Forum (4GMF) unlike WWRF is an upcoming consortium with focus on the Open Wireless Architecture (OWA). According to the 4GMF, their outlook toward OWA is an effort to compliment WWRF research efforts. As of March 2004, near 50 'Fortune 500' companies had shown interest in working with 4GMF, according to 4GMF claims. 4GMF expects to sign agreements to expand its leadership in worldwide markets with local and global players.³

Apart from these global telecommunications standardizing bodies, consortiums, and forums there are multiple interest groups that: 1) Focus on specific technologies like the IEEE 802.11 project, IPv6 Forum, SDR Forum, Bluetooth Special Interest Group (SIG), and IETF and 2) Relate to specific regions like the UMTS forum, ETSI, and ANSI accredited TIA. There exist a plethora of such established and upcoming global/regional 4G and technology specific development forums, which are working towards similar goals. It is worth noting that while having such a diverse range of players does contribute to innovation and the development of new ideas, such distributed, multi-layered efforts may become a huge challenge for standardization, especially with the outlook of 'Open Wireless Architecture' and integration for 4G. Furthermore, while efforts to establish a grand vision for 4G are called for, they are occurring in a context in which technology providers are still struggling with the implementation of 3G.

4. The legal and regulatory framework of advanced wireless

Like the technological base, the legal and regulatory framework in which next generation wireless services evolve differs widely between platforms. Moreover, there are substantial differences between the EU and the US, especially in the 3G area. Table 1 summarizes key features.

4.1 The European 3G framework

While the EU was able to gain consensus on the technical standard for 3G, this was just about the only point of agreement. The UMTS licensing framework emerged from measures at the European and national levels. At the European level key principles for broadband wireless were defined in the UMTS Decision of 1998 (128/1999/EC). Prior to that decision, important

³ <http://www.4gmf.org/>

cornerstones of European mobile communications policy were set in the GSM Directive of 1987 (87/372/EEC), the Mobile Directive of 1996 (96/2/EC), as well as in the Licensing Directive of 1996 (97/13/EC). In the early 1990s, the EU had argued in favor of a more unified European

Table 1: Advanced wireless market designs

	EU	US
	3G	
Market entry	License required; awarded in auction, beauty contest, or hybrid	Not yet defined, likely auction. 2G spectrum can be used for 3G services
Roll-out requirements	Detailed roll-out provisions, relaxed after initial deployment delays	Minimal requirements likely, if any
Network sharing	Initially not permitted; allowed after initial delays subject to competitive test	Generally permissible as long as it does not reduce competition
Spectrum markets	No, spectrum can only be returned without refund to government	Rudimentary secondary markets exist, likely more fully developed in near future
Market entry cost	High investment cost, aggravated in some countries by high costs of spectrum	High investment cost, cost of spectrum not yet known but likely not a significant factor
Protection against interference	Strong, specified in license	Strong, specified in license
	WiFi/WiMAX	
Market entry	License free; subject to meeting certain transmitter specifications; in some countries only indoor use in 5GHz band	License free, subject to meeting certain transmitter specifications
Roll-out requirements	None	None
Network sharing	Permitted	Permitted
Spectrum markets	N/A	N/A
Market entry cost	Low	Low
Protection against interference	None	None

Sources: Own research.

approach to spectrum management. However, national governments insisted on their powers in setting spectrum policy. As a result, when UMTS spectrum was assigned to network operators, a diverse set of approaches with respect to the licensing method (auctions, beauty contest) and the terms of the licenses emerged across Europe. A comparison of the methods and outcomes is presented in Table 2.

Table 2: 3G Mobile licensing in selected countries

Country	No. of licenses	Mobile incumbents	Method	Date awarded	Total amount paid (10 ⁶ US\$)	Price/POP paid by highest bidder (US\$ PPP) (4)
Austria	6	4	Auction	November 2000	618	15.83
Belgium	4	3	Auction	March 2001	421.2	16.67
Denmark	4	3	Sealed bid auction	September 2001	472	27.07
Finland	4	3	Beauty contest	March 1999	Nominal	0.00
France	4	3	Beauty contest + fee	July 2001	553 each, plus 1% of revenue (3)	11.37
Germany	6	4	Auction	August 2000	46,140	114.44
Greece	3	3	Hybrid(2)	July 2001	414	14.55
Italy	5	4	Hybrid(2)	October 2000	10,180	42.75
Netherlands	5	5	Auction	July 2000	2,500	51.24
Norway	4	2	Beauty contest + fee	November 2000	88	3.06
Spain	4	3	Beauty contest + fee	March 2000	480	3.44
Sweden	4	3	Beauty contest	December 2000	Nominal	0.00
Switzerland	4	2	Auction	December 2000	119.8	4.95
UK	5	4	Auction	April 2000	35,400	130.20
US	180(1)		Likely auction	Not set yet	Not available	N/A

Notes: (1) Six service providers offer national coverage; the remaining service providers operate on a regional or local level only. (2) Combination of pre-selection of bidders and auction. (3) Initial bid was 4.52 billion but was reduced. (4) From Bauer (2003).

Sources: ITU (2002) and Bauer (2003).

These differences were partly responsible for the widely varying costs of spectrum (see Table 2). These costs were determined both by the method with which governments distributed the spectrum (in most cases auctions), the number of licenses issued, as well as the participants' business plans and willingness to pay. The high level of the bids, particularly those in the earlier auctions, surprised both governments and participants. While in early reactions governments tended to explain the phenomenon as normal functioning of the market and thus a desired outcome of the auction assignment method, there is evidence, albeit presented after the fact, that the auctions were poorly conceived (Cramton 2002; Klemperer 2004). There is also evidence that, contrary to official declarations, the licensing process was conceived to maximize government revenues (Melody 2001)).⁴

Soon after the spectrum auctions were completed, operators and financial institutions started to lobby policy makers to ease their financial burden. Several proposals were floated in EU member states. These include:

- Repurchase of the spectrum by the government and lease back to the operators. This model would convert a fixed cost into a variable cost.
- Staggered payment of the license fee in several installments.
- Discounts on the amount bid by the operators.
- Ability for the operators to release spectrum on a secondary market.

As the enactment of such measures would likely have a devastating effect on the future credibility of public policy, policy makers were hesitant to adopt them. Any such “regulatory re-contracting” would undermine future efforts to design efficient policy and invite strategic behavior. Nevertheless, the EU started to fundamentally rethink future spectrum policy. In addition, measures were adopted at the EU and member state level to facilitate forms of facilities sharing, which is one strategy for reducing the cost of the 3G network rollout. A spectrum of sharing options, ranging from site sharing, tower sharing, radio access network sharing, geographical split of the network, to a full common shared network is possible. These options differ with respect to how far they reach into the core network. Although the strategy initially raised concern about the possibility of anti-competitive behavior, the Commission of the European Communities principally endorsed the notion of network sharing in a Communication dated March 20, 2001 (Commission 2001). In subsequent statements, the Commission clarified

⁴ This is illustrated by the fact that, after the exorbitant sums paid in Germany and the UK, the Dutch government faced the criticism of not having maximized revenues for the public purse.

that sharing arrangements would have to comply with relevant competition principles and that each agreement would be subject to scrutiny. With principles developed by the German regulator, RegTP, commonly seen as a model case (RegTP 2001), several national regulatory authorities have approved sharing agreements, in general not reaching further than a shared radio access network as long as the operators maintain logically separate facilities.

4.2 The US 3G framework

Compared to the EU, the U.S. has pursued a less ambitious and focused 3G policy. The U.S. had chosen a 2G band allocation in the 1.9GHz range that prevented use of the band designated in most other countries for 3G. On October 13, 2000, President Clinton signed a Memorandum establishing guiding principles for the Federal Communications Commission (FCC) and the National Telecommunications and Information Administration (NTIA), who are jointly responsible for civil and government spectrum use, to identify 3G spectrum. “[T]he Presidential Memorandum directed the Secretary of Commerce to work cooperatively with the FCC: (1) to develop a plan to select spectrum for third generation wireless systems by October 20, 2000; and (2) to issue by November 15, 2000 an interim report on the current spectrum uses and potential for reallocation or sharing of the bands identified at the 2000 World Radiocommunication Conference that could be used for 3G systems.”⁵ Although the FCC has already issued a Spectrum Policy Statement in 1999, the attempts to meet the deadline failed.

Based on work done the NTIA, the Department of Defense (DOD), other federal agencies, and the FCC, the FCC issued a Final Report addressing issues in the 2500-2690 GHz band and NTIA issued a Final Report on the 1755-1850 MHz bands. A second report on the use of spectrum on the viability of accommodating advanced mobile wireless systems in the 1710-1770 MHz and 2110-2170 MHz bands was released in July 2002 (NTIA 2002). It identified 90 MHz of spectrum (45 MHz lower and 45 in the upper band) that could be used for 3G services. In November 2002, the FCC issued a Notice of Proposed Rulemaking to establish rules for the definition and deployment of 3G services.⁶ In September 2001, the FCC had also added a mobile allocation to the 2500-2690 MHz band. As this band was occupied with Instructional Television Fixed Services (ITFS) and Multichannel Multipoint Distribution Service (MMDS),

⁵ See <http://www.fcc.gov/3G/> and <http://www.ntia.doc.gov/ntiahome/threeg/>.

⁶ U.S. Federal Communications Commission, *In the Matter of Service Rules for Advanced Wireless Services in the 1.7 and 2.1 GHz Bands*, WT Docket No. 02-353

the agency did not relocate the existing licenses. Final rules have not yet been issued for the proposed 90 MHz spectrum allocations. However, the FCC has pursued relatively flexible spectrum allocation policy since the mid-1990s. Therefore, service providers are able to use their PCS spectrum to configure 3G services should there be market demand.

4.3 The European and U.S. WiFi and WiMAX frameworks

In the unlicensed services the European and U.S. market design is more alike than in 3G. In both regions, market entry into unlicensed services is relatively free, only subject to minimal etiquette requirements. Most importantly, national regulatory agencies have imposed power limits and “listen-before-talk” protocols on devices. Whether these are efficient approaches to managing unlicensed bands is presently the subject of an intense controversy. Although etiquettes are intended to mitigate interference problems, unlike licensees in the 3G bands, users of unlicensed bands do not enjoy protection against interference. Pundits of open access to spectrum claim that sophisticated digital devices will render interference problems obsolete. However, the empirical proof of this claim has yet to be observed. The conditions in the unlicensed bands have facilitated a jolt of innovation and the rapid diffusion of WLANs in homes and public spaces. However, the availability of a technology does not necessarily translate into a successful business model. The vulnerability to entry by competing service providers may prevent the emergence of a ubiquitous infrastructure and limit unlicensed applications to local access networks (Bauer 2004).

5. Sector economics and business strategy

A central claim of our paper is that the specific technical and regulatory conditions of next generation wireless services shaped the evolution of these markets. This section briefly reviews the experience in the European Union and in the U.S. (and provides a few hints at Southeast Asia). We will address the effects of the entry conditions and market design in 3G as well as the evolution and the outlook for WiFi and WiMAX.

5.1 The evolution of advanced wireless markets

The European deployment vision for UMTS foresaw widespread coverage by the end of 2003. Business forecasts at the beginning of 2000 likewise anticipated rapid growth rates of mobile data revenues. For example, in its market outlook, Arthur Andersen and J. P. Morgan anticipate that by 2010 more than 50% of the sector revenues would originate from mobile data. In

hindsight, these forecasts and visions look overly ambitious and were based on very optimistic assumptions as to the demand for advanced mobile services. So far, no clear “killer application” or “killer cocktail” has emerged. Demand-side weaknesses were aggravated by the financial difficulties of important operators suffering from the combined effects of the IT market downturn and winner’s curse after the spectrum auctions. Presently, 3G services are gradually introduced across Europe, several years behind the envisioned time line and much slower than hoped. Although no reliable data are available, the major operators across Europe have either begun offering 3G services or are in the process of doing so. In the U.S., the major carriers offer mobile data services but most of them are based on 2.5G technology platforms. For the purposes of this paper, detailed information was collected on the market penetration strategies of 3G operators during the second half of 2003 (for more details see Lin 2003) and again in the spring of 2004. The following two sub-sections summarize key data for the United Kingdom and the present situation in the U.S.

5.1.1 United Kingdom 3G and mobile data market

The U.K. mobile data market became one of the pioneers for the next-generation mobile data services when Hutchison 3G UK launched 3G services in the first quarter of 2003. At that time the U.K. mobile market was highly developed. By 2002 there were already nearly 50 million cellular subscribers.⁷ Among European countries, only Germany (59 million) and Italy (52 million) had more subscribers. In 2002, its mobile penetration rate was 84%, which was higher than the EU average of 78% and the average global penetration (19%).⁸ Since the U.K. had a large base of cellular subscribers, experts expected that the U.K. would have great potential for success in the mobile data market.

There were at one time four mobile operators in the U.K.: Vodafone, BT Cellnet, Orange and One2One. While Vodafone had the biggest market share among them (28%), the difference between market shares was small and in March 2001 they were nearly equal (Olla and Patel 2002).⁹ However, in 2002 and 2003 the market changed. BT Cellnet merged with mmO2 and the company’s name changed to O2 UK. One2One was annexed by T-Mobile and provided

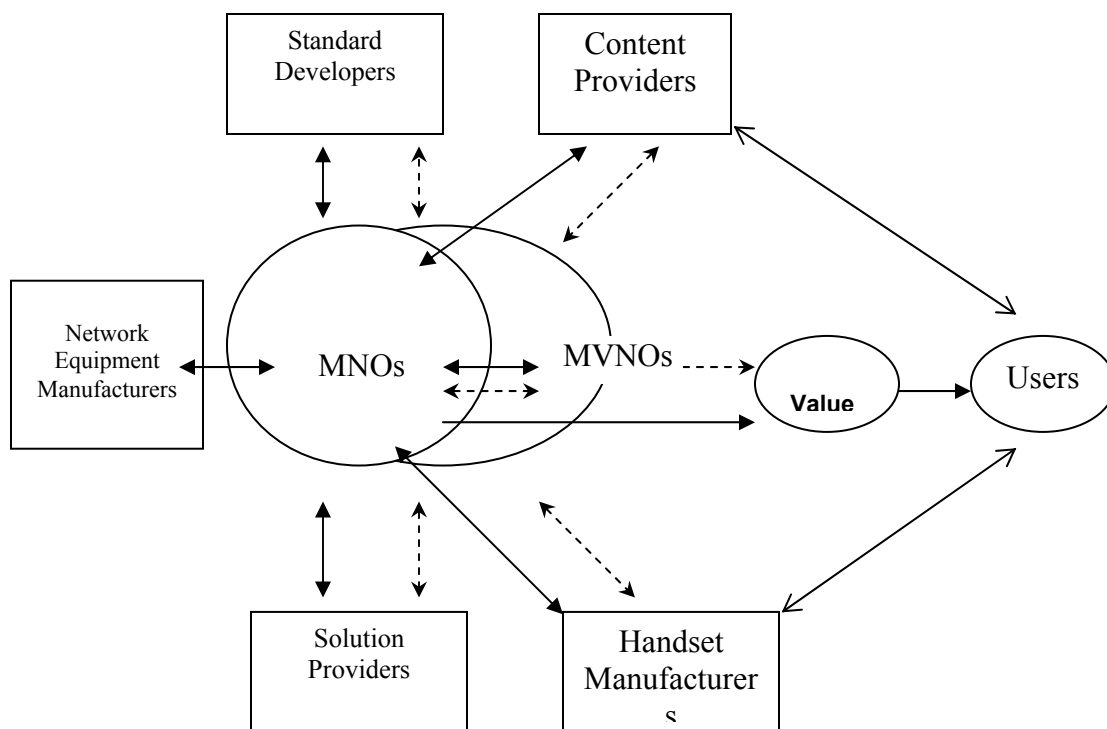
⁷ Source: ITU http://www.itu.int/ITU-D/ict/statistics/at_glance/cellular02.pdf, 2002. By the end of 2002, there were 49.9 million subscribers in the UK.

⁸ Source: ITU. http://www.itu.int/ITU-D/ict/statistics/at_glance/cellular02.pdf, 2002. The average is based on 196 countries for which data were available.

⁹ Vodafone: 28%; BTCellnet: 26%; One2One: 21%; Orange: 25%.

services under the brand name of T-Mobile. In addition to these mergers, new entrants came into the mobile market. One of these was Hutchison 3G UK, which acquired one of the five 3G spectrum licenses and is the only network operator to completely concentrate on 3G services. Beside these five MNOs, an MVNO, Virgin Mobile, also participates in this market. Virgin Mobile is a half-half joint venture between Virgin Group and One2One.¹⁰ Without its own network, Virgin Mobile uses infrastructure owned by One2One, but established a new brand for providing mobile services.

Figure 1: Value Network of the UK Mobile Data Market



Source: Lin (2003).

The structure of the U.K. mobile data market can be roughly represented in the Figure 1. Vodafone, O2, Orange, T-Mobile and Hutchison 3G UK are the network operators as well as the mobile Internet service providers. As network operators, these five companies establish technological cooperation with the standard developers and with network equipment manufacturers. As mobile Internet service providers, these five companies work with the content providers, solution providers and handset manufacturers for delivering mobile Internet services.

¹⁰ Source: Virgin Mobile http://www.virginmobile.com/mobile/media_centre/media_tenthings.jsp, Sep. 2003.

to users. Virgin Mobile is the MVNO in this structure. Instead of acquiring a spectrum license and deploying the mobile network by itself, it just delivers services over another operator's network. The MVNO strategy simplifies coordination with the standard developers and network equipment manufacturers. Virgin Mobile can concentrate on negotiating with content providers, solution providers and handset manufacturers.

The U.K. mobile market is very competitive. To acquire more subscribers, each operator has its own special offers for service plans and handsets (Lin 2003). Five of six British mobile operators provide 2G and 2.5G services: Vodafone, O2, Orange, T-Mobile, and Virgin Mobile. In general, the service items they provide are very similar. They all offer services such as text and picture messaging, WAP content, E-mail, ringtone and wallpaper downloads, and games. In 2003, Hutchison 3G's "3" was the only 3G service in the U.K. It offers customers more services than the others through its 3G network. For instance, it provides the first and the only 2-way mobile video calling in the U.K.¹¹ and a wider variety of games, VOD, and MOD than other operators.

5.1.2 United States 3G and mobile data market

Although the U.S. has the world's second largest mobile market,¹² it lags behind some West-European and Asian countries in the development of mobile data. The launch of 3G, namely CDMA2000 1XEV-DO, has occurred first in only very limited areas, although coverage is expanding. These launches typically target business customers before being offered to consumers. One of the earliest launches was made by a regional carrier, Monet Mobile, in some cities of the central states in Oct. 2002.¹³ The other one was launched by Verizon Wireless in San Diego and Washington D.C. in Oct. 2003. The U.S. market is served by six nationwide mobile operators and more than a hundred regional operators. Verizon Wireless is the largest with a market share estimated at around 23%.¹⁴ Ranked by the mobile market share, the next five operators are Cingular Wireless (15.4% market share), AT&T Wireless (14.7% market share), Sprint PCS

¹¹ By October 2003, Hutchison 3G was the only provider of video calling services.

¹² Source: ITU <http://www.itu.int>, October 2003.

¹³ Source: 3G Today <http://www.3gtoday.com>, Oct. 2003

Monet's CDMA2000 1XEV-DO services offered in Sioux Falls (South Dakota), Fargo (North Dakota), Grand Forks (North Dakota), Bismarck (North Dakota), Eau Claire (Wisconsin), Superior (Wisconsin), Duluth (Minnesota) and Moorhead (Minnesota).

¹⁴ Source: FCC CMRS Eighth Competition Reports <http://www.fcc.gov>, 2003

Out of 141.8 million total subscribers in the U.S., Verizon had 43.49 million subscribers in the end of 2002.

(10.4% market share), Nextel (7.5% market share) and T-Mobile (7.0% market share).¹⁵ Strictly speaking, there is no dominant player in the U.S. mobile market. This situation makes the U.S. mobile market very competitive and with stiff price competition. Due to the difficulty of increasing the number of subscribers, operators focus on mobile data as a means of increasing ARPU.

In addition to the six mobile operators, there is one new entrant in the market. Virgin Mobile USA, which acts as an MVNO, is a joint venture of Virgin Group and Sprint PCS and uses the Sprint PCS network. Although it only had 0.25% market share by the end of 2002, it still seems to have a bright future. First, its number of subscribers is rapidly growing. It acquired 350,000 customers within the first 6 months since its initial rollout at July 2002¹⁶ and had 500,000 subscribers at April 2003¹⁷. Second, its mobile data usage rate is much higher than the others'. While 20% of the U.S. cellular subscribers sent or received SMS in 2002, more than 50% of the Virgin Mobile's subscribers used the service¹⁸.

Compared with other countries which have launched 3G service, by the end of 2003 U.S. mobile operators mostly offered basic mobile data services like text messaging, IM (Instant Messaging), ringtones and graphics, E-mail, information alerts, games, and web browsing for the text-based content. None of them provide video telephone. Five of them (except Nextel and Virgin Mobile) provide MMS, but only in the regions where there are the advanced-technology networks. MOD and VOD are also limited (see Lin 2003 for more details). Due to the different market targets and the limitation of network bandwidth, some operators have different services from others. Sprint PCS's main target users is business users, so it offers PCS Business Connection especially designed for them. Virgin Mobile USA's main target users are the teenagers and young adults. Focusing on their demand on music, movies and fun, Virgin Mobile USA targets entertaining content. As for Nextel, it only provides basic services because of the limitation of transmission speed.

Some operators bundle data services and create a brand name for the combination. Customers have a variety of mobile data services included in one plan, such as AT&T's mMode, Sprint PCS's PCS Vision, T-Mobile's t-zone, and Virgin Mobile USA's VirginXtras. These

¹⁵ Source: FCC CMRS Eighth Competition Reports <http://www.fcc.gov>, 2003

¹⁶ Source: Virgin Mobile USA <http://www.virginmobileusa.com>, Oct. 2003

¹⁷ Source: Total Telecom <http://www.totaltele.com>, April 22, 2003

¹⁸ Source: Virgin Mobile USA <http://www.virginmobileusa.com>, Oct. 2003

plans have the advantage of streamlining advertising and marketing for the operators. Among those service brands, Verizon Wireless's Get It Now is an exception. Even though it gave a brand name for the collection of the services, customers do not have to get them all and can subscribe to the services individually just like other general data services.

5.1.3 WiFi and WiMAX

Whereas the evolution of 3G so far has been slower than expected, WiFi has experienced a boom and is expected to continue on a fast growth trajectory. Similar to the introduction of other IT services, WiFi is surrounded by a high level of enthusiasm as to its growth and revenue potential but the actual diffusion rates so far do not measure up to early expectations (Bar and Galperin 2004). With the caveat that these forecasts are afflicted with a high degree of uncertainty, table 3 summarizes representative forecasts for the WiFi market. One outstanding observation is the expected parallel development of the number of hotspots and the total revenues generated from them for Europe and the U.S. Between 2003 and 2007, a near ten-fold growth is expected in the number of deployed hotspots. Revenues in the U.S. are expected to grow somewhat slower than in the EU due to the higher intensity of competition. Given the conditions in the related 3G markets, as will be discussed in more detail below, it is not surprising to find that hotspot services in the EU tend to be more integrated in the operations of 3G service providers (ON World Inc. 2004). At this point in time, no market diffusion data are available for WiMAX. However, its success or failure will likely affect the developments in the WiFi markets.

Table 3: Growth forecasts for the WiFi market 2003-2007

	Hotspots			Revenues (US\$ million)		
	EU	US	World	EU	US	World
2003	8,900	9,900	40,900	50	60	212
2004	21,300	25,800	93,700	72	76	296
2005	40,700	50,000	184,100	108	113	477
2006	64,500	76,200	287,500	192	200	836
2007	93,300	103,200	404,200	373	365	1,436

Source: ON World Inc. (2004).

5.2 Policy, standardization and sector evolution

The few years of observations available for the EU allow a tentative assessment of the effect of the licensing policies on the evolution of the 3G market and indirectly on the WiFi market. As was discussed above, a core claim of neoclassical economics is that in the presence of perfect capital markets spectrum fees determined in auctions only affect shareholders and not the real developments in the market. An empirical check of the potential impact of license fees on the stock market valuation of mobile operators is complicated by the fact that the overall industry suffered from a significant downturn after March 2000. To test whether companies which paid higher prices for spectrum were hit harder than other mobile operators, Zhang (2003) studied the affect of license fees on the difference between the stock market valuation of individual companies and the NASDAQ information technology index. Using such a corrected measure of stock market values, she finds a strong negative correlation between the price paid for spectrum and market valuation. However, the empirical record also indicates that the license policy may have had significant real effects. Although traditional theory would predict that companies facing high sunk costs would accelerate investment to deploy service sooner, companies whose market valuation dropped apparently had difficulty funding investment into 3G infrastructure, slowing the pace of deployment. It is difficult to estimate the associated loss in economic welfare on the consumer side. Hausman (2004) estimated welfare losses due to delayed introduction of 2G services in the U.S. of a staggering magnitude. An educated guess would therefore have to place the potential welfare losses due to delayed introduction in the double-digit billion \$ range. It is even more difficult to assess the potential negative impact on European competitiveness and innovation overall. The high license payments and slow market growth may imply that 3G services will not break even for nearly 10 years (Bauer, Maitland et al. 2001; Björkdahl, Bohlin et al. 2004), if ever.

It is even more difficult to evaluate the U.S. situation. On the one hand, U.S. operators can use their 2G spectrum to deploy 3G services (but have done so only reluctantly). On the other hand, they were awarded less bandwidth than their European counterparts. It is probably fair to state that the price of PCS spectrum, which was also awarded in auctions, does not play a strong role in explaining the slow diffusion of advanced wireless in the U.S. For example, Bauer (2003) found that 2G license fees, admittedly much lower than the 3G prices in some European countries, had no lasting impact on mobile prices. Moreover, of the \$45 billion formally paid for

licenses, only one fourth was actually collected so far by the U.S. Treasury. Thus, compared to the real investment expenditures (topping \$50 billion for upgrades during the last few years alone) license fees are not a decisive factor. In comparison, the UMTS license fees paid in Europe are nearly equal to the anticipated investment expenditures. It seems that the slow U.S. growth is the result of a combination of business strategies to amortize existing network infrastructure. Due to the absence of a mandatory standard, four digital networks were rolled out in parallel, probably increasing the overall investment cost. It may also indicate weak demand for true 3G services, which in turn is the result of several factors. One is the widespread access to computers at work and at home. Very likely, fixed Internet access is partially substituting for mobile access. Secondly, life patterns and habits in the U.S. differ from the present leading countries in Southeast Asia (see Lin 2003 for more details). Third, advanced mobile services offered in the U.S. are not packaged in ways that are attractive to consumers. This may have to do with the specific way the value chain is configured. Until very recently, U.S. operators resisted revenue sharing with content providers, as is typical for the very successful models in Japan and Korea. Furthermore, the pricing of services is complicated and intransparent. Together with intense price competition, these factors have resulted in a declining Average Revenue per User (ARPU) (Parks Associates 2003). Although the valuation of mobile operators in the U.S. also declined significantly in the wake of the IT market collapse, it was less severe than the reduction of operators who paid high prices for UMTS spectrum. Overall, apart from bottlenecks created by the slow designation of spectrum for advanced licensed wireless operations, it seems that the U.S. market is in a better position to manage the transition to 3G services than large parts of the European industry.

5.3 The 3G-WiFi/WiMAX nexus

The developments in 3G, WiFi and WiMAX markets are interrelated. Industry experts anticipate that within the next five years, a growing number of mobile devices will be WiFi-enabled. For example, On World (2004a, pp. 19-21) estimates that by 2007 95% of all laptops, 55% of all PDAs and handhelds, and 55% of all mobile phones will be WiFi enabled. At present, WiFi, WiMAX and 3G services are mostly complements, with 3G being the more effective technology in providing coverage and mobility and WiFi and WiMAX superior with regard to data rates (Lehr and McKnight 2003). However, as WiFi and WiMAX evolve, they may be able to overcome these shortcomings and develop into full-fledged substitutes for 3G. Due to the lower

market entry costs and potential scalability of WiFi, such a prospect must be a serious threat for operators with high sunk investments in 3G licenses and/or networks. Therefore, there will be a strong incentive for these operators to also control or at least have a strong presence in the WiFi market. This anticipated effect is already clearly visible in the European markets. The incentive for such an integration strategy will likely be less the lower the sunken investment into the substitute technology. Whether such a strategy can be successful will depend on a number of factors. First, it will depend on which business models will succeed in the WiFi/WiMAX areas. While WiFi may be a market with low entry barriers, creation of an integrated market environment is a significant challenge. The open access conditions leave potential operators vulnerable to competition and may thus reduce the ability to recover infrastructure investment. A large grass-roots movement envisions building a seamless network of openly accessible WiFi access points (see, for example Sandvig 2003). Even if this model may not serve all user needs, it may cut into the expected revenues streams of potential commercial service providers and render investment projects unattractive. Due to the local nature of WiFi this effect may be mitigated by the ability of service providers to enter exclusive agreements with property owners (thus exclusive use rights granted in spectrum licenses are in part replaced by exclusive contracts based on land ownership). As in the cellular industry before, at present, WiFi roaming and availability are major impediments to market growth.

6. Conclusions

The goal of this paper was to theorize and document the co-evolution of technology, policy, and sector economics. A major claim was that these three sets of factors mutually influence and constrain each other and that the overall evolution of advanced mobile services is an emergent property from their interaction. In particular we are interested in sector performance as indicated by the level of diffusion of services, the mix of technologies and services as well as the speed of innovation. Evidence of the interaction and its implications were presented for both the 3G and WiFi/WiMAX technologies in both the European and U.S. markets. From these comparisons we derive the following conclusions.

The design of advanced wireless markets, defined by market access rules, service roll-out obligations, and third-party access rules has an influence on the speed of investment and hence the speed with which innovative services are introduced. While they have created substantial revenues for the public sector, mistaken spectrum auction policies in Europe have resulted in

high direct and indirect costs for operators and users. In the EU, these costs were aggravated by the specific market design. In particular, the inflexibility of spectrum use and initially rigid roll-out requirements reduced the ability of operators to adjust their investment policies in response to the high uncertainty in the market. Thus, while innovative services may be offered by these operators this speed may create financial hardships which are detrimental to the market in the long run. Furthermore, the introduction of innovative services does not guarantee widespread availability or adoption, thereby affecting the level of diffusion of services. This can be contrasted with the more organic approach pursued in the U.S. There the slow designation of additional 3G spectrum in combination with other factors, such as the reliance on multiple standards, wide availability of fixed Internet access, and complex service and pricing plans, all have contributed to more gradual investments in 3G infrastructure and a comparatively slow diffusion of 3G services.

If we look to the effects of the interaction between technology, policy and strategy in the WiFi or WiMAX markets we find that these technologies for which the market design is less restricted have experienced a rapid evolution of services that has rendered the concept of “generations” of wireless services obsolete. Rather, “3G” and “4G” services are presently introduced in parallel. The different sector design (licensed versus unlicensed) and economic conditions (higher degree of scalability for WiFi but higher cost to reach wide-area coverage) have created an environment of potentially fierce competition between these platforms. If we compare the EU and U.S. market estimates for the diffusion of these technologies are similar. However, service providers and types of services offered may differ. Given the high sunk costs in 3G in Europe, it can be expected that operators will try to gain a strong presence in WiFi and WiMAX markets. In contrast, the U.S. market may exhibit a higher degree of diversity. At this point, it is difficult to foresee which model will turn out to be superior in the medium and long term.

Another significant aspect of market design that has interactions with technology and strategy and implications for the mix of technologies and services is the approach to standards. For example, the success of 2G in the EU and relatively slow development of 2G in the US has long been attributed to the benefits from the committee-based standardization approach. But, with the issues of 3G rollout in EU, which demands a complex, difficult and costly transformation from 2G and 2.5G infrastructure, requirements of additional spectrum, and

innovations from US-based Qualcomm in CDMA technology, have raised questions and doubts about the idea of the committee-based standardization approach.

Finally, these findings concerning the implications of the interaction between technology, policy and strategy lead us to the general conclusion that given the overall complexity of advanced wireless markets there is a risk that grand policy strategies backfire. Thus, it may be a superior policy design strategy to implement the most flexible market design to strengthen the ability of market participants to adjust flexibly to evolving conditions. Our comparison of two technologies and markets demonstrates the high degree of both complexity and uncertainty in these contexts. In the future such an approach toward licensing could lead to institutional competition between the licensed and unlicensed regime, rather than exclusive reliance on one or the other, which may facilitate a process of evolutionary learning from which a superior solution, both from a technological and economic standpoint, may emerge.

References

- Bar, F. and H. Galperin (2004). "Building the Wireless Infrastructure: From Cordless Ethernet Archipelagos to Wireless Grids." Communications & Strategies(54): 45-68.
- Bauer, J. M. (2003). "Impact of License Fees on the Prices of Mobile Service." Telecommunications Policy 27: 417-434.
- Bauer, J. M. (2004). Spectrum Management and the Evolution of the Mobile Services Industry. R. Cooper and G. Madden.
- Bauer, J. M., C. F. Maitland, et al. (2001). Advanced Wireless Communications Infrastructure: Technical, Economic, and Regulatory Conditions of UMTS Network Deployment. Delft, The Netherlands, Technical University of Delft.
- Benkler, Y. (2003). Some Economics of Wireless Communications. Rethinking Rights and Regulations: Institutional Responses to New Communication Technologies. L. F. Cranor and S. S. Wildman. Cambridge, MA, MIT Press: 149-192.
- Björkdahl, J., E. Bohlin, et al. (2004). "Financial Assessment of Fourth Generation Mobile Technologies." Communications & Strategies(54): 71-94.
- Commission, E. (2001). The Introduction of Third Generation Mobile Communications in the European Union: State of Play and the Way Forward. Communication from the Commission to the Council, the European Parliament, the Economic and Social Committee and the Committee of the Regions. Brussels, Commission of the European Communities.
- Cramton, P. (2002). Spectrum Auctions. Handbook of Telecommunications Economics. Volume 1. Structure, Regulation and Competition. M. E. Cave, S. K. Majumdar and I. Vogelsang. Amsterdam, Elsevier Science: 605-639.

Dixit, A. K. and R. S. Pindyck (1994). Investment under Uncertainty. Princeton, NJ, Princeton University Press.

Farrell, J. and G. Saloner (1988). "Coordination Through Committees and Markets." The Rand Journal of Economics **19**(2): 235.

Faulhaber, G. R. and D. J. Farber (2003). Spectrum Management: Property Rights, Markets, and the Commons. Rethinking Rights and Regulations: Institutional Responses to New Communication Technologies. L. F. Cranor and S. S. Wildman. Cambridge, MA, MIT Press: 193-226.

Funk, J. L. and D. T. Methe (2001). "Market- and committee-based mechanisms in the creation and diffusion of global industry standards: The case of mobile communication." Research Policy **30**(4): 589.

Gandal, N., D. Salant, et al. (2003). "Standards in wireless telephone networks." Telecommunications Policy **27**(5,6): 325.

Gruber, H. (2001). "Spectrum Limits and Competition in Mobile Markets: The Role of License Fees." Telecommunications Policy **25**: 59-70.

Hausman, J. A. (2004). Cellular 3G Broadband and WiFi. Frontiers of Broadband, Electronic and Mobile Commerce. R. Cooper and G. Madden. Heidelberg, Germany, Physica-Verlag: 9-25.

Hazlett, T. H. (2001). "The Wireless Craze, the Unlimited Bandwidth Myth, the Spectrum Auction Faux Pas, and the Punchline to Ronald Coase's 'Big Joke': An Essay on Airwave Allocation Policy." Harvard Journal of Law and Technology **14**(2): 335.

ITU (2002). Internet for a Mobile Generation. Geneva, International Telecommunication Union.

Keil, T. (2002). "De-facto standardization through alliances--Lessons from Bluetooth." Telecommunications Policy **26**(3,4): 205.

Klemperer, P. A. (2004). Auctions: Theory and Practice. Princeton, NJ, Princeton University Press.

Kwerel, E. and J. Williams (2002). A Proposal for a Rapid Transition to Market Allocation of Spectrum. OPP Working Paper Series 38. Washington, D.C., Federal Communications Commission.

Lee, J.-R., D. E. O Neal, et al. (1995). "Planning for dominance: A strategic perspective on the emer." R & D Management **25**(1): 3.

Lehr, W. and L. McKnight (2003). "Wireless Internet Access: 3G vs. WiFi?" Telecommunications Policy **27**(5-6): 351-370.

Lin, Y.-C. (2003). The Mobile Data Market: Industry Structure and Business Cooperation. Department of Telecommunication, Information Studies and Media. East Lansing, Michigan, Michigan State University.

Melody, W. H. (2001). "Spectrum Auctions and Efficient Resource Allocation: Learning from the 3G Experience in Europe." Info **3**(1): 5-10.

Noam, E. M. (1998). "Spectrum Auctions: Yesterday's Heresy, Today's Orthodoxy, Tomorrow's Anachronism. Taking the Next Step to Open Spectrum Access." Journal of Law and Economics **56**(2): 765-790.

NTIA (2002). An Assessment of the Viability of Accommodating Advanced Mobile Wireless (3G) Systems in the 1710-1770 MHz and 2110-2170 MHz Bands. Washington, DC, National Telecommunications and Information Administration.

Olla, P. and N. V. Patel (2002). "A Value Chain Model for Mobile Data Service Providers." Telecommunications Policy **26**(9-10): 551-571.

- ON World Inc. (2004). *European Hotspots: A Rapidly Growing Ecosystem*. San Diego, CA, ON World Inc.
- Parks Associates (2003). *Disconnected: Consumers and the Mobile Phone Industry*. A White Paper. Dallas, TX, Parks Associates.
- Reed, D. P. (2002). *How Wireless Networks Scale: The Illusion of Spectrum Scarcity*. Paper presented at the International Symposium on Advanced Radio Technology. Boulder, CA.
- RegTP (2001). *Auslegung der UMTS-Vergabebedingungen im Hinblick auf neuere technische Entwicklungen*. Bonn, Regulierungsbehörde für Telekommunikation und Post.
- Shapiro, C. and H. R. Varian (1999). *Information Rules: A Strategic Guide to the Network Economy*. Boston, MA, Harvard Business School Press.
- Spiller, P. T. and C. Cardilli (1999). "Towards a Property Rights Approach to Communications Spectrum." *Yale Journal on Regulation* **16**(1): 53-83.
- Werbach, K. (2004). "Supercommons: Toward a Unified Theory of Wireless Communications." *Texas Law Review* **82**: 863-972.
- Zhang, L. (2003). *Impact of License Fees on Corporate Financial Situation and 3G-rollout Status*. East Lansing, Michigan, Michigan State University.